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Crop Response and Weed Control from New Herbicide Combinations in Water-Seeded Rice (*Oryza sativa*)[1]

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Abstract. In five field experiments from 1986 to 1988, herbicides were evaluated alone and in combinations for weed control in water-seeded rice. Combinations of bensulfuron with either molinate or thiobencarb applied into the paddy water at the 2-leaf stage of rice, controlled all broadleaf and sedge weeds, and 92% or more early watergrass. These combinations were equivalent to a commercial standard of molinate at the 2-leaf stage followed by a separate application of bentazon to the drained paddy at midtillering. **Nomenclature:** bensulfuron, 2-[[[[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]methyl]benzoic acid; molinate, S-ethyl hexahydro-1*H*-azepine-1-carbothioate; thiobencarb S-[(4-chlorophenyl)methyl]diethylcarbamothioate; bentazon, [3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide]; rice, *Oryza sativa* L. 'M-202'; early watergrass, *Echinochloa oryzoides* (Ard.) Fritsch. #[3] ECHOR.
Additional index words. Rice weed control, bensulfuron, water-seeded rice, ECHOR, CYPDI, SCPMU, SAGMO, HETLI, AMMCO.

INTRODUCTION

Water seeding is the broadcasting of pregerminated or dry rice seed into the flooded paddy. This method of seeding is widely practiced in California and to a lesser extent in the southern United States, Australia, and Europe. The risk of crop injury from herbicides is greater in water-seeded than in drill-seeded or transplanted rice (7, 8) and fewer herbicides are available. Water seeding suppresses barnyardgrass, *Echinochloa crus-galli* (L.) Beauv. and watergrass (1, 3, 7), and enhances the activity of herbicides used for grass control. Water seeding, however, results in a more diverse aquatic weed flora than in dry-seeded systems (1, 5, 7).

In California, molinate or thiobencarb is applied in the first two weeks of rice growth to control barnyardgrass and watergrass (3). Bentazon or MCPA (4-chloro-2-methylphenoxy)acetic acid, controls the most important aquatic sedges, smallflower umbrella sedge (*Cyperus difformis* L. # CYPDI) and ricefield bulrush (*Scirpus mucronatus* L. # SCPMU); and the aquatic broadleaf weeds, California arrowhead (*Sagittaria montevidensis* Cham. & Schlecht. # SAGMO), purple ammannia (*Ammannia coccinea* Rottb. # AMMCO) and ducksalad (*Heteranthera limosa* (Sw.) Willd. # HETLI). The floodwater must be lowered to expose small weeds for foliar absorption of bentazon and MCPA (3, 10). But lowering or draining the floodwater 1) stimulates the germination and growth of new weeds, and 2) may discharge previously applied molinate and thiobencarb into public waters[4], thereby placing herbicide registration at risk.

The separate application of two herbicides coupled with the drainage to apply either of them is no longer regarded as good management for California rice (3). The purpose of this study was to compare the effectiveness of bensulfuron, a new rice herbicide (4, 9), in combinations with molinate or thiobencarb applied into static floodwater for broad-spectrum weed control.

MATERIALS AND METHODS

Experiments were conducted at the Rice Experiment Station, near Biggs, CA, in 1986 and 1987 on a Stockton clay (fine, montmorillonitic, thermic, Typic Pelloxerert); and in Sutter County near Pleasant Grove, CA, in 1986, 1987, and 1988 on a Capay clay (fine, montmorillonitic, thermic, Typic Argixeroll). At the Biggs site, phosphorus and nitrogen (9.9 kg P ha^{-1} and 18 kg N ha^{-1} as ammonium phosphate sulfate) were broadcast by airplane and incorporated by harrowing.

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[3]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 309 W. Clark St., Champaign, IL 61820.
[4]Cornacchia, J. W., D. B. Cohen, G. W. Bowes, R. J. Schnagl, and B. L. Montoya. 1984. Rice herbicides: Molinate and thiobencarb. California State Water Resources Control Board, Spec. Proj. Rep. No. 84-4.

Additional nitrogen (120 kg N ha^{-1} as ammonium sulphate) was drilled to 5 to 7 cm. At the Sutter County site, phosphorus and nitrogen were drilled as ammonium phosphate sulphate and additional nitrogen was applied by injection of ammonia at the same rates as those applied at the Biggs site.

Each experimental layout was designed to prevent mixing of herbicides from one plot to another in the floodwater. Four by 7 m plots were enclosed with 1 m wide by 0.5 m high levees. Rows of plots were separated by alternating irrigation and drainage ditches. Water was siphoned into individual plots from the irrigation ditches and maintained at a depth of 8 to 11 cm. Treatments were arranged in a randomized complete block design with four replications.

Pregerminated rice seed was aerially sown at 144 kg ha^{-1} after flooding. Formulated bensulfuron (60DF) and bentazon (4S) were applied at a constant 210 kPa with a CO_2-pressurized backpack sprayer in 187 L ha^{-1} water at 0.07 and 1.1 kg ha^{-1} respectively. Molinate and thiobencarb were broadcast by hand as 10G formulations at 4.5 kg ha^{-1}. All herbicides except bentazon were applied into 7 to 11 cm static floodwater at the 2- to 3-leaf stage of rice, one immediately following the other in the combination treatments. At the early tillering stage of rice, plots to be treated with bentazon were drained by siphoning and reflooded 24 h after the application. Nonphytotoxic oil (0.5% v/v) was added to the bentazon treatments.

Control of individual weed species was evaluated by visual ratings where 0% = no control relative to the most heavily infested plot of each experiment; and 100% = all weeds killed. Untreated plots were not always rated zero for each weed species. Weeds were counted only in the untreated plots within two randomly placed 0.07 m^2 clear plastic rings to determine the weed density of each species (Table 1). Rice stand was measured as a visual rating where 0% = no rice stand and 100% = normal stand. Rice plant height was measured from the soil surface to the tip of the panicle. Individual plots were harvested with a small plot combine[5] in a 2.3 m wide swath by the length of the plot. Grain moisture was measured and yields were corrected to a basis of 14% moisture.

Visual ratings for weed control were tested for homogeneity using Bartlett's test. Heterogeneous data were arcsine transformed and again tested for homogeneity before analysis of variance was performed. Means were separated using the Least Significant Difference (LSD) test. Although original nontransformed data are presented in the tables, means were separated using the LSD generated from arcsine transformed data where necessary. Treatments having no variation among the individual observations were excluded from the analysis to prevent underestimation of the LSD (6). Combined treatment averages are presented where no interactions occurred among experiments. Where significant interactions occurred the appropriate LSD was calculated to separate experiment by treatment means.

Table 1. Weed counts in the untreated plots for each experiment.

	Sutter County			Biggs	
Weed species	1986	1987	1988	1986	1987
	plants m^{-2}				
Early watergrass	33	12	3	118	7
Ricefield bulrush	ne[b]	ne	ne	251	179
Smallflower umbrella sedge	287	104	337	ne	ne
Ducksalad	69	11	22	ne	ne
California arrowhead	22	ne	4	ne	ne
Purple ammannia	9	ne	17	ne	ne

[a]Rice Experiment Station near Biggs, CA.

[b]ne = not evaluated due to absence or very low presence of species.

RESULTS AND DISCUSSION

Crop response. Visual ratings for rice stand response showed no treatment by experiment interaction. None of the herbicides alone, nor the commercial standard of molinate followed by bentazon, reduced rice stand (Table 2). Combinations of bensulfuron with thiobencarb or molinate, however, significantly lowered rice stand suggesting that bensulfuron with either of these two herbicides may slightly increase the potential for rice injury. In all experiments, the rice plants fully recovered within two weeks after the application of the combination treatments. Rice plant height was not affected by the combination treatments and the data are not presented.

The experiment by treatment interaction for grain yield was significant, principally because yields from the bentazon treatments were highly variable among experiments due to differing proportions of broadleaf versus early watergrass at each site and/or year (Table 1). Bentazon does not control early watergrass (3, 10).

[5]SWECO Model 324, Sutter Welding & Equipment Co., Sutter, CA 95982.

Table 2. The response of crop stand and yield to herbicide treatments in water-seeded rice[a].

Treatment	Rate	Stand average[c]	Grain yield				
			Sutter County			Biggs[b]	
			1986	1987	1988	1986	1987
	kg ai ha^{-1}	%	kg ha^{-1}				
Untreated	. . .	98 a	3 650 p	6 330 lmn	3380 p	3830 op	6690 k-n
Molinate	4.5	96 a	9 400 c-h	10 410 abc	4370 no	7490 i-m	8450 e-j
Thiobencarb	4.5	96 a	10 290 a-d	8 040 g-k	6970 j-n	6630 k-n	7720 h-l
Bentazon	1.1	98 a	5 930 mn	6 320 lmn	7330 j-m	3510 p	9070 c-i
Bensulfuron	0.07	95 ab	9 050 c-i	8 610 d-j	8130 f-k	6300 lmn	8460 e-j
Molinate fb[d] bentazon	4.5 fb 1.1	97 a	9 970 a-e	11 580 a	7500 i-l	8540 e-j	9290 c-h
Molinate + bensulfuron	4.5 + 0.07	93 b	9 660 c-g	10 550 abc	7770 h-l	8210 f-k	9760 b-f
Thiobencarb + bensulfuron	4.5 + 0.07	89 c	11 360 ab	10 120 a-e	7910 h-l	8630 d-j	9120 c-i

[a]Within a variable, means followed by the same letter do not differ significantly at the 5% level according to LSD test.

[b]Rice Experiment Station, near Biggs, CA.

[c]Four tests Sutter County (1986 and 1987) and Rice Experiment Station (1986 and 1987).

[d]fb = followed by.

In the Biggs 1987 and Sutter 1988 experiments, where early watergrass populations were low, bentazon-treatment yields were equal to those of the best treatments. But in 1986, where early watergrass populations were high, bentazon-treatment yields were significantly lower than those of the best treatments. Rice yields were significantly higher in bensulfuron, molinate, and all herbicide combination treatments throughout all five experiments (Table 2). Rice yields from the use of new combinations of bensulfuron with either molinate or thiobencarb were equal to those resulting from the standard sequential treatment of molinate followed by bentazon. The early rice injury caused by the combination treatments did not affect yield.

Weed control. Smallflower umbrella sedge and ricefield bulrush control showed significant experiment by treatment interactions for weed control with both weed species (Table 3). Molinate controlled 90 and 70% of smallflower umbrella sedge and ricefield bulrush in the two 1987 experiments, but 23 and 28% in the two 1986 experiments. This interaction may have resulted from differences in molinate uptake under higher temperatures in 1987 relative to lower (and more typical) temperatures in 1986 (2). Thiobencarb controlled smallflower umbrella sedge in all experiments, but failed to control ricefield bulrush. Bentazon, bensulfuron and all the combinations controlled both of these weed species, but there were differences in the success

Table 3. Percent control of smallflower umbrellasedge and ricefield bulrush to herbicide treatments in water-seeded rice[a].

Treatment	Rate	CYPDI[b]			SCPMU[b]	
		Sutter County			Biggs[c]	
		1986	1987	1988	1986	1987
	kg ai ha^{-1}	%			%	
Untreated	. . .	0 g	10 fg	0 g	0 f	8 ef
Molinate	4.5	23 f	90 a-d	63 e	28 d	70 c
Thiobencarb	4.5	95 abc	70 de	81 a-e	18 de	3 f
Bentazon	1.1	78 b-e	78 b-e	71 cde	75 bc	100 a
Bensulfuron	0.07	100 a	98 ab	100 a	85 bc	93 ab
Molinate fb[c] bentazon	4.5 fb 1.1	93 abc	80 a-e	89 a-d	84 bc	100 a
Molinate + bensulfuron	4.5 + 0.07	100 a	100 a	100 a	99 a	100 a
Thiobencarb + bensulfuron	4.5 + 0.07	100 a	100 a	100 a	100 a	100 a

[a]Nontransformed data are presented in the tables, but means were separated using LSDs from arcsine transformed data. Within a weed species means followed by the same letter do not differ significantly at the 5% level according to LSD test.

[b]CYPDI, smallflower umbrella sedge; SCPMU, ricefield bulrush.

[c]Rice Experiment Station, near Biggs, CA.

[d]fb = followed by.

Table 4. Percent control of ducksalad, California arrowhead and purple ammannia to herbicide treatments in water-seeded rice in Sutter County[a].

Treatment	Rate	HETLI[b] 1986	HETLI[b] 1987	HETLI[b] 1988	SAGMO[b] Average[c]	AMMCO[b] Average[c]
	kg ai ha^{-1}	%				
Untreated	. . .	20 gh	13 gh	14 gh	13 b	3 c
Molinate	4.5	15 hi	18 gh	0 i	9 b	0 c
Thiobencarb	4.5	28 fgh	60 de	0 i	0 b	21 b
Bentazon	1.1	84 cd	33 fg	85 cd	99 a	100 a
Bensulfuron	0.07	100 a	83 cd	95 abc	100 a	100 a
Molinate fb[d] bentazon	4.5 fb 1.1	86 bcd	48 ef	91 abc	100 a	96 a
Molinate + bensulfuron	4.5 + 0.07	100 a	100 ab	100 a	100 a	100 a
Thiobencarb + bensulfuron	4.5 + 0.07	100 a	100 ab	100 a	100 a	100 a

[a]Nontransformed data are presented in the tables, but means were separated using LSDs from arcsine transformed data. Within a weed species means followed by the same letter do not differ significantly at the 5% level according to LSD test.

[b]HETLI, ducksalad; SAGMO, California arrowhead; AMMCO, purple ammannia.

[c]Two tests, Sutter County (1986 and 1987).

[d]fb = followed by.

of control. In 1986 and 1988 bentazon alone, for example, controlled less smallflower umbrella sedge than bensulfuron alone. Combinations of molinate or thiobencarb with bensulfuron controlled 100% of the smallflower umbrella sedge and essentially all of the ricefield bulrush including infestations exceeding 250 plants m^{-2} (Table 1). Combinations with bensulfuron controlled the two sedge species equivalent to the standard commercial treatment of molinate followed by bentazon.

California arrowhead and purple ammannia control showed no experiment by treatment interaction and treatment averages for each species were combined (Table 4). Such interactions occurred for ducksalad, and the results were separated for each experiment (Table 4). Ducksalad control by thiobencarb was not acceptable, as results varied from 0 to 60%. This variability could not be explained by weather or management related factors, but has been previously noted by Smith (8). Bentazon controlled California arrowhead and purple ammannia in all experiments, and ducksalad in two of the three experiments. In 1987, when control of ducksalad by bentazon was lowest (33%), it was applied too late and the spray was partially intercepted by the taller growing rice and weeds. Thus competition by uncontrolled ducksalad as well as early watergrass contributed to the lower yields with bentazon in the 1987 Sutter experiment. The commercial standard of molinate followed by bentazon controlled California arrowhead and purple ammannia; but because the bentazon was applied late in 1987, ducksalad was not controlled. Bensulfuron alone controlled all California arrowhead and purple ammannia and 83% or more ducksalad in all three experiments. Combinations of

Table 5. Percent control of early watergrass to herbicide treatments in water-seeded rice[a].

Treatment	Rate	Sutter County 1986	Sutter County 1987	Sutter County 1988	Biggs[b] 1986	Biggs[b] 1987
	kg ai ha^{-1}	%				
Untreated	. . .	5 no	30 kl	10 mno	0 o	0 o
Molinate	4.5	100 a	98 abc	95 a-d	100 a	88 a-d
Thiobencarb	4.5	84 d-g	63 ghi	95 abc	88 c-f	59 hij
Bentazon	1.1	8 mno	17 lmn	10 mno	5 mno	20 klm
Bensulfuron	0.07	55 hij	70 fgh	40 ijk	43 jk	51 hij
Molinate fb[c] bentazon	4.5 fb 1.1	100 ab	97 a-d	99 ab	99 abc	100 ab
Molinate + bensulfuron	4.5 + 0.07	100 ab	98 abc	99 ab	94 a-d	100 ab
Thiobencarb + bensulfuron	4.5 + 0.07	94 a-d	70 e-h	90 b-e	95 a-d	91 b-e

[a]Nontransformed data are presented in the tables, but means were separated using LSDs from arcsine transformed data. Means followed by the same letter do not differ significantly at the 5% level according to LSD test.

[b]Rice Experiment Station, near Biggs, CA.

[c]fb = followed by.

bensulfuron with molinate or thiobencarb were 100% effective on all three broadleaf aquatic weeds in these experiments.

Early watergrass control showed treatment by experiment interactions and the results of each experiment are presented separately (Table 5). Early watergrass was not affected by bentazon and only partially controlled by bensulfuron (approximately 50%). Thiobencarb acceptably controlled early watergrass in the 1986 and 1988 experiments but not in 1987. As a result of higher temperatures in 1987, some early watergrass was too advanced for thiobencarb control. Early watergrass beyond the 2-leaf stage is controlled poorly by this herbicide in water-seeded rice (10). The combination of thiobencarb and bensulfuron controlled early watergrass effectively except in the 1987 Sutter experiment. Molinate alone, or in combination with bensulfuron, controlled early watergrass in all experiments equivalent to the commercial standard of molinate followed by bentazon.

General. Continuous flooding suppresses the growth of early watergrass and contributes to the efficacy of molinate and thiobencarb (3, 7). Bentazon requires foliar contact and to achieve this, the paddy water must be drained to expose small weeds (10). Drainage for bentazon often stimulates the germination and growth of new weeds. Furthermore, rice field water containing residues of previously applied molinate or thiobencarb has polluted public waters of California when drained for bentazon application. In these experiments, combinations of bensulfuron with either molinate or thiobencarb were applied directly into static floodwater which was held continuously at 8 to 11 cm deep until drained for harvest. These combinations controlled early watergrass, three common broadleaf weeds and the two most important sedges in California rice. Rice yields, other crop responses, and weed control were equivalent or better than the commercial standard of molinate followed by bentazon. Furthermore, the success of bensulfuron in static floodwater alone or in combination eliminates the requirement to drain the paddy as with previously used broadleaf herbicides.

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LITERATURE CITED

1. Barrett, S.C.H., and D. E. Seaman. 1980. The weed flora of Californian rice fields. Aquat. Bot. 2:242–250.
2. Bayer, D. E. 1987. Temperature as a modifying environmental factor of herbicidal response. Proc. Calif. Weed Conf. 39:114–116.
3. Bayer, D. E., J. E. Hill, and D. E. Seaman. 1989. Rice (*Oryza sativa*). p. 296 *in* Principles of Weed Control in California, 2nd Ed. Thomson Publications, Fresno, CA.
4. Hill, J. E. 1988. New herbicides and improved management strategies for California rice. Proc. Calif. Weed Conf. 40:100–102.
5. Eastin, E. F. 1981. Weed management systems for U.S. rice. p. 539–547 *in* D. Pimentel, ed. Handbook of Pest Management in Agriculture. Vol. 3. CRC Press, Inc., Boca Raton, FL.
6. Little, T. M., and F. J. Hills. 1978. p. 164, Agricultural Experimentation: Design and Analysis, John Wiley and Sons, New York.
7. Seaman, D. E. 1983. Farmer's weed control technology for water-seeded rice in North America. p. 167–177, *in* Proc. Conf. Weed Control in Rice. Int. Rice Res. Inst., Los Banos, Laguna, Philippines.
8. Smith, R. J. 1988. Weed control in water- and dry-seeded rice *Oryza sativa*. Weed Technol. 2:242–250.
9. Takeda, S., T. Yuyama, R. C. Ackerson, R. C. Weigel, R. F. Sauers, L. W. Neal, D. G. Gibian, and P. K. Tseng. 1985. Herbicidal activities and selectivity of a new rice herbicide DPX-F5384. Weed Res. Japan 30: 284–289.
10. University of California. 1983. Integrated pest management for rice. Calif. Div. Agric. Sci., Berkeley, CA. Publ. 3280.